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ROLE OF ESTUARINE WATERS IN GULF FISHERIES

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The commercial fisheries of the Gulf of Mexico have experienced a phenomenal growth during the past 20 years. In 1940 landings of the Gulf states, Florida (west coast), Alabama, Mississippi, Louisiana and Texas totaled 250 million pounds valued at 10 million dollars and increased to 700 million pounds valued at 85 million dollars in 1957 (Figure 1). In 1940, the Gulf accounted for only 10 percent of the total value of U. S. fisheries and in 1957 accounted for nearly 25 percent of the U. S. total. In value, three Gulf states are included among the ten leading states, Texas ranks third in the nation and Florida and Louisiana follow in fifth and eighth place respectively (Power, 1959).

The growth of the Gulf fishery has several facets of interest. One is that the fishery is conducted in shallow coastal waters, contrasted with open ocean fishing such as for tuna and groundfishes. Another facet is that the species contributing to this fishery are all "estuarine-dependent". That is, at some period of their life, these species inhabit intra-coastal waters such as bays, lagoons and marshes of the [illegible] (Present-day usage of estuary often includes all areas in which [illegible] is daily mixing of fresh and saline waters in contrast to the [illegible] restricted definition of tidal-river mouths. For lack of a better [illegible] we consider the term estuary as synonymous with all intra-[illegible] waters).

[illegible] purposes of this paper are to: (1) show the contribution of estuarine-dependent species to the commercial fisheries of the Gulf of Mexico, (2) outline some of the environmental features of the estuary and (3) give examples of man-made changes which influence this environment.

ESTUARINE ECOLOGY

Estuarine-dependent species such as shrimp, menhaden and oysters dominate the Gulf fishery, and account for approximately 90 percent of the annual fisheries value. These estuarine-dependent species can be separated into two general categories—transients and residents. Of the commercially important species, the majority are transients and are represented by fishes such as menhaden *(Brevoortia)* and mullet *(Mugil)* and by invertebrates such as shrimp *(Penaeus)*. These particular species may be referred to as "quasi-catadromous" in that the adults spawn offshore and the young move inshore to less saline estuarine waters. Oysters *(Crassostrea)* characterize the resi-

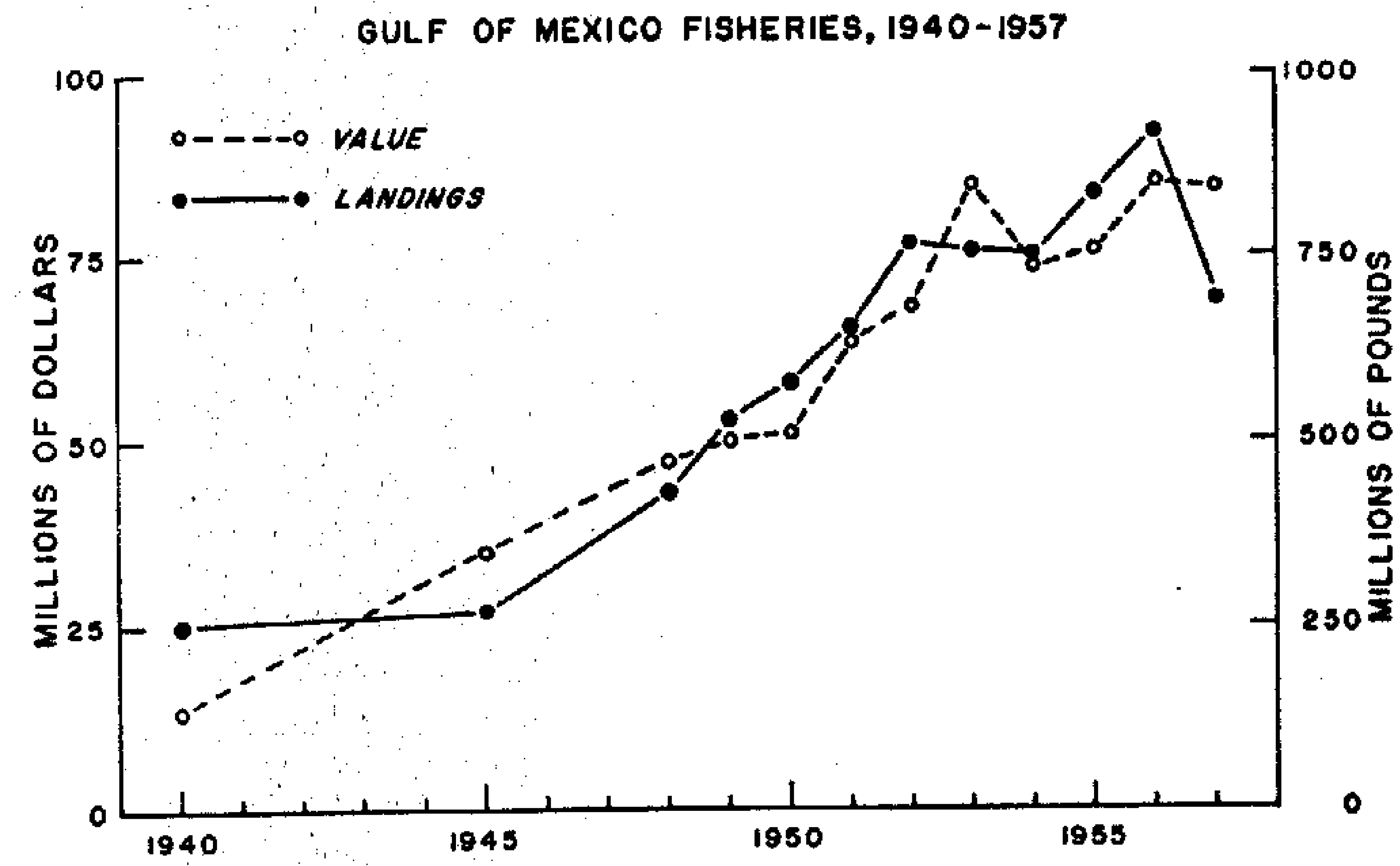

Figure 1. Landings and value of Gulf fisheries, 1940-1957.

dent species and spend their life within the estuarine boundaries.

The life history of shrimp exemplifies the existence of the transient organisms. Adult shrimp spawn offshore and their post larvae enter the estuaries through passes between barrier islands and move to the estuarine nursery areas. These nursery areas may be lesser bays, lagoons, marshes, or bayous. Within a period of approximately three months, following growth and development to juveniles or immature adults, the shrimp migrate through the passes into the open Gulf.

Several species of penaeid shrimp contribute to the Gulf fishery and it is of interest to note the progression in habitat use of two of these species. In Galveston Bay, Texas, white shrimp (*Penaeus setiferus*) and brown shrimp (*P. aztecus*) inhabit the same general areas but do so during different seasons of the year (Chin, 1959). Brown shrimp dominate in the spring and whites in the summer and fall. The brown shrimp remain in the estuary for shorter periods and migrate seaward at smaller sizes than the white shrimp. Our knowledge of shrimp physiology, behavior, population dynamics and ecology is not well enough advanced so that we can outline the precise role of estuarine waters and their influence on shrimp populations.

The life history of the oyster, a resident species of estuaries, has been summarized by Butler (1953) and Hofstetter (1959). Oysters spawn in the bays from May to September. The eggs and larvae develop rapidly and within approximately two months the larvae must find a suitable surface for attachment. If successful, they become permanently sessile adults. Because of its ability to adapt to varying environmental conditions, the oyster is a common species of many Gulf estuaries.

How important are the estuaries to our fisheries and how are the fisheries affected by natural and man-made changes? Attempts to answer these questions emphasize our limited knowledge about estuaries. We shall present some of the results of research that have given insight to the complexity of the estuarine environment and its potential value to the Gulf fisheries.

Gulf estuaries normally result from the formation of offshore bars, although many occur in deltaic formations. They are funnel or oval shaped and the majority have maximum dimensions of less than 15 miles. Although depth-sections reveal shallow, depression shapes, most Gulf estuaries are transected by oyster reefs and sand bars. The average depth is usually less than 10 feet. According to Shuster (1959), such shallow bodies of water are extremely productive as most of their volume is exposed to high light intensities. Additionally, the bottom itself is exposed to strong light, affording a greater area for growth of sessile plants.

The estuarine tides of the Gulf are of small amplitude, generally less than two feet. Irregular changes of water level of greater magnitude are caused by winds. The latter changes are probably the most important in the water interchange of these estuaries and wave action stirs the bottom redistributing the nutrients.

The majority of the Gulf estuaries are within salt marshes or have marshes around much of their periphery. In effect, the marshes extend the shoreline and the producing area of the estuary. Nutrients are flushed from the marshes into the estuaries, and many estuarine organisms periodically forage in the marshes. Starr (1956) describes the importance of marshes as areas of vitamin B_{12} production and Provasoli and Pintner (1953) lists vitamin B_{12} as a growth requirement of phytoplankton organisms.

Measurements of primary productivity show that estuaries are more productive than the continental shelf and deep oceans and often exceed certain agricultural areas, grasslands and shallow lakes (Odum, 1959). The summer productivity was at least 1.5 times that of winter in Gulf estuaries and the greater number and poundage of macroorganisms was present during the summer period (Odum, personal communication).

In these shallow estuaries, changes in water temperature occur rapidly; summer temperatures as high as 88° F. and winter temperatures as low as 45° F. are not uncommon. Changes of 20° F. within a five-day period may occur in the winters. Rapid temperature changes have caused the death of millions of marine organisms (Gunter, 1941).

In regard to salinity, Gulf estuaries are of two general types. First is the hypersaline estuary in which the salinity varies from approximately $36^0/_{00}$ of the open Gulf to $80^0/_{00}$ or higher in the innermost areas. The second is that in which the salinity varies from less than $1^0/_{00}$ in the headwaters to between 20 and $35^0/_{00}$ near the mouth. Most estuaries are in the second group. Changes of this magnitude limit the number of species which inhabit given portions of the estuary. Many authors, for example, Ladd (1951) found that the number and abundance of mollusk species were higher in polyhaline bays and passes (salinity—15-$31^0/_{00}$) than either in the Gulf (salinity over $32^0/_{00}$) or in the closed bays and headwaters (salinity less than $15^0/_{00}$). Mackin and Wray (1949) state that of all basic environmental factors, salinity has the greatest influence on oyster mortality. Their statement is qualified by the remark that high salinity alone does not produce death, rather, mortality follows the infestations and/or infections of shell pests, predators, and parasites that require high salinity for optimum development. Thus in low-salinity, estuarine waters the incidence of oyster mortality from these causes is much reduced. In spite of this relation, salinity *per se* does not seem to be the exclusive limiting factor.

The inflowing freshwater is one of the principal sources of nutrients in estuaries. Runoff varies from practically none in the Laguna Madre with no permanent streams entering it, to the tremendous flow of the Mississippi River. That the growth of estuarine phytoplankton depends upon nutrients from the land is shown by their increase following periods of heavy rainfall (Nash, 1947). Pratt (1949) states that fertilization of a salt-water pond increased the standing crop of phytoplankton as much as tenfold. Small, repeated applications caused a larger increase than a single large application. The organic detritus from marshlands and rivers is an important source of food. Indeed, some organisms may consume such detritus as their principal food source. This material is decomposed by bacteria and fungi and a large number of organic and inorganic substances are released (Odum, 1959).

MAN-MADE CHANGES

In addition to the natural-occurring changes, man in his progress has an ever-increasing influence on estuarine waters. Man-made changes include engineering structures on river basins flowing into the estuaries as well as dredging and channelization in the estuaries proper. These projects may alter the environment and affect the estuarine populations. For example, reduced outflow of a dammed river may reduce the nutrient supply or increase the salinity to the detriment of certain estuarine species. On the other hand, controlled outflow may stabilize the estuarine environment and provide conditions more favorable for a given species. Specific knowledge is not sufficient to interpret the results of the environmental changes. Pritchard's (1953) work on the distribution of oyster larvae in relation to hydrographic conditions exemplifies the need for such specific information and the coordinated efforts of physical and biological scientists. He showed that sub-surface currents influenced the distribution of oyster larvae and accounted for their concentration at the head of the estuary. However, the larvae exhibited some ability to remain grouped, independent of the circulation and mixing processes. He concluded that "... physical scientists, when attempting to apply physical theories to biological problems, must take into account the possible modifying factors peculiar to the organism involved. Some responsibility must then rest with the biologists to supply information concerning the organism which might modify the influence of the physical factors." Extensive planning and full understanding of the particular estuarine environment is necessary to determine the possible effects on biological populations.

In the past, municipal, industrial and agricultural uses of our water resources have been the major concern of water-use projects. However, during the development of these projects, the importance of other uses has become evident and the evaluation of effects has broadened in scope. For example, fishery and recreational uses must be considered and the evaluation must include more than the immediate project area to account for indirect or secondary changes. An instance of a secondary change was mentioned during a previous Conference (see Trans. Twenty-first No. Amer. Wildl. Conf. p. 436). The discussion concerned the Santee-Cooper hydro-electric project in South Carolina. An increased river flow in one system was expected to carry the accompanying sediment increase. However, on reaching the estuary, the suspended material settled into an upstream tidal flow and was deposited in the estuary, creating a dredging cost of a million dollars annually. Sedimentation changes such as this are of particular concern in the Gulf because of the shallowness of the estuaries.

As an example of the magnitude of these undertakings we can cite the Mississippi-Gulf Outlet Project of the Corps of Engineers. Already under construction, this project is designed to provide a 70-mile long navigable channel from New Orleans to the open Gulf. The

channel is being dredged to a depth of 40 feet and a bottom width of 500 feet. It traverses a system of bayous, embayments and marshes on the eastern side of the Mississippi Delta, and crosses Breton and Chandeleur Sounds. Waters in the vicinity are fished commercially for shrimp, oysters, and industrial fishes. Current research on the prevailing hydrological and biological conditions will provide a basis for interpreting possible effects on commercial fishery resources.

Some progress towards integrated programs of evaluating the effects of these engineering projects is in evidence. Conservation agencies of each Gulf state, such as the Texas Game and Fish Commission, and the U. S. Fish and Wildlife Service review proposed projects and when applicable, submit recommendations to mitigate damages to marine and estuarine as well as freshwater populations. However, the existing scale of research must be accelerated to keep pace with the ever-increasing number of man-made changes in the estuaries.

SUMMARY

Fisheries of the Gulf of Mexico have increased in value from 10 to 85 million dollars and in weight from 250 to 700 million pounds during the past 20 years. Estuarine-dependent species such as shrimp, menhaden and oysters dominate these fisheries and account for 90 percent of the landed value. Shrimp and most fishes are dependent on the estuaries during the all important early phase of their life history. Oysters, on the other hand, complete their entire life cycle in the estuary.

Most Gulf estuaries can be characterized as variable environments, in which, the inhabitants must have broad tolerance limits. These shallow embayments are subject to rapid changes in such factors as temperature and salinity. Some estuaries are hypersaline but in most, the salinity varies from less than $1^0/_{00}$ to $25^0/_{00}$. River discharge and flushing of salt marshes are probably the principal sources of nutrients.

The number of man-made changes in the estuaries and inflowing streams is increasing rapidly and expanded research is sorely needed to evaluate the effects of such changes on the estuarine species.

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DISCUSSION

MR. RIGGS: [Oklahoma]: I am curious about the staining technique that you use.

MR. SKUD: The shrimp are injected with hypodermic needles. For the most part we have used a fast green and find it more successful than some of the other biological dyes. On injecting this into the shrimp, the entire body discolors immediately. However, within a 24-hour period, the stain settles in the gill, and we have recovered shrimp that have been held in the pond for as long as six months, and the stain is still recognizable in the gills.

CHAIRMAN BARTHOLOMEW: A problem on which I would like to have a brief discussion is the pollution of estuary waters by detergents.

MR. SKUD: Work on pollution of many sorts has been quite varied in the Gulf and I can give no evidence for work specifically concerned with detergents. Very little of this is known and further, as far as growth and vegetation in the estuaries, also very little is known.

MR. SIGLER [New Hampshire]: Have you done any work on the importance of estuaries on forage fishes which attract game fish?

MR. SKUD: I would only say indirectly. We are accumulating some information on forage and game fishes which inhabit the estuarine areas but nothing specific on forage fishes as such.